Measurement of Bicuspid Aortic Heart Valves through Digital Image Processing
Thomas Carter ’16, Ada Ng ’16, Gina Buzzelli ’16
Faculty Advisor: Professor Taikang Ning

Abstract
This capstone project applies image processing techniques to quantify the severity of stenosis in bicuspid aortic heart valves. Stenosis occurs as the heart ages, when calcium deposits and scarring builds up on the aortic cusps, the valve narrows, and in turn blood flow is restricted. This type of heart disease is very common in older individuals and is identified through interpreting echocardiogram images. The challenge of our capstone project is to assist doctors in identifying and quantifying the severity of stenosis in bicuspid aortic heart valves so they can offer preventative care. This medical problem is translated to an engineering design project with the use of MATLAB software. Through image enhancement techniques, an echocardiogram image of a bicuspid valve is made more readable. We take advantage of the contrast between the cusps and the blood vessel to perform image segmentation. Following this, the valve region is automatically detected by our program. Subsequently, the area is calculated and compared to known values of healthy aortic valves. The result of our program closely resembles the accuracy obtained from manual measurement. This project provides an alternative diagnostic tool for the quantification of stenosis.

Design Constraints
• Limited access to echocardiogram images of bicuspid aortic heart valves due to the HIPAA Privacy Rule protecting medical records.
• Variability amongst echocardiogram images prevents the program from adapting to all test images.

Design Process
The design process of the program consist of two major sections: applying image processing techniques and valve location determination. The goal of applying image processing techniques was to extract the most useful data from the echocardiogram image so that it would be more easily readable by MATLAB. Certain techniques were chosen based off of research, understanding the technical process behind the function, and trial and error. There is no straightforward equation or set of techniques that will give the best image. Next, an accurate valve detection program had to be created. From this, patterns needed to be identified which set the valve region of interest apart from any other region or noise. Various techniques were contemplated based on distinguishing features we recognized, and our programming capability.

Final Design
The final design includes three aspects:

Image Enhancement
Used to alter the contrast of the original echocardiogram image in order to produce a new image with more pronounced and defined boundaries for further analysis. The image enhancement techniques include RGB to grayscale conversion, Laplacian of Gaussian edge detection, filling in holes, connecting edges, and removing unwanted noise.

Image Segmentation
Used to detect and identify the aortic valve and segment this region from the rest of the image. The program includes a color change and cluster determination algorithm to locate the circular aortic valve and determine the radius of this region. With the above information, a white circular mask is first created over the entire region, turning the rest of the image to black in order to get rid of any unwanted structures. The circular mask is then restored and the output of this segmentation is effectively the circular aortic valve.

Measurement of the Valve Area
Used to determine the cross sectional area of the aortic valve to provide a quantification of the severity of stenosis. The program measures the cross sectional area using the radius value and the formula for the area of a circle. A pixel to distance ratio is determined based on the given scale in the echocardiogram images. The result is an area in square centimeters, which can be compared to known values of aortic valves with stenosis.

Results
7 echocardiogram images were used to test the program. The accuracy rate is ~70% (5/7 images correctly diagnosed). Below are some examples of the program output:

Conclusion
The final system is able to apply image processing techniques on echocardiograms to produce a new image with more defined boundaries. It can also successfully identify the valve location, segment this region from the rest of the image, and provide a measurement for the cross sectional area of the valve. This measurement was compared to known values of aortic valves with stenosis to provide a quantification of the severity of stenosis. Although the program may not be 100% accurate, any type of measurement is better than no measurement. Ultimately, the program aims to develop a systematic approach to provide an objective measure of the cross sectional area of the valve. The program intends to provide an assistive tool to allow doctors to make an informative diagnosis of the severity of stenosis. In the future, the program can be trained with more test images to improve accuracy and be able to take measurements in real time and show them on the device’s screen.

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